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DEPENDENCE OF TENSIONS ARISING IN THE STEM OF THE KNITTING NEEDLE WHEN THE NEEDLE HITS THE WEDGE ON THE INFLEXIBILITY OF THE NEEDLE-WEDGE PAIR

The efficiency of knitting machines, in particular their productivity and fabric quality, largely depends on the durability of the needles, which, in turn, depends on the dynamic loads that arise in the zone of impact interaction of the needles with the wedges of knitting systems.

Previous studies have shown that when a knitting needle hits a wedge, shock waves of stress appear in its shaft, which is one of the main causes of needle failure (destruction of the needle hook, etc.). In this case, when solving the problem of determining the magnitude of the stresses arising in the needle rod, the case of a hard impact of the needle (rod) on the wedge is considered. In reality, when the needle hits the wedge, an elastic impact occurs, due to the rigidity of the needle-wedge pair.

Studies show that an effective way to reduce the dynamic loads acting on the needle during knitting machine operation is to reduce the inflexibility of the needle-wedge pair. However, the issue of the influence of the inflexibility of the needle-wedge pair on the dynamics of tensions arising in the needle stem has not been practically studied, which creates certain problems in the design of knitting machines.

The object of research is the knitting machine needle and the process of its interaction with the wedges of knitting systems. When solving the problems set in this work, modern methods of theoretical research were used, based on the theory of shock wave propagation in flat stem elements during longitudinal impact.

The research objective is to investigate the influence of the inflexibility of the needle-wedge pair of a knitting machine on the tensions that arise when the needle hits the wedge, and to develop a method for the influence of the inflexibility of the needle-wedge pair on the impact tensions in the needle stem during its interaction with the wedge during the knitting process.

Analysis of the obtained dependencies allows us to conclude that the inflexibility of the needle-wedge pair affects the magnitude of the tensions in the needle stem caused by the shock wave. At the same time, a decrease in inflexibility contributes to a decrease in the magnitude of the tensions in the needle stem.

As is known, the needle has a complex geometric shape. Therefore, when the needle hits the wedge, a complex stress field arises in its body, which depends on the geometric shape of the needle. The obtained equations are only some approximation of the description of the process of changing the tensions in the needle body when it hits the wedge.

Keywords: *knitting machine, needle, wedge, tensions in a needle, inflexibility of pair needle-wedge.*

ПЛЕШКО СЕРГІЙ
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ЗАЛЕЖНІСТЬ НАПРУЖЕНЬ, ЩО ВИНИКАЮТЬ У СТІБЛІ СПИЦИ ПРИ УДАРІ ГОЛКИ ОБ КЛИН, ВІД НЕРОЗКІБНОСТІ ПАРИ ГОЛКА-КЛИН

Ефективність роботи в'язальних машин, зокрема їх продуктивність та якість полотна, значною мірою залежать від довговічності роботи голок, яка, у свою чергу, залежить від динамічних навантажень, що виникають в зоні ударної взаємодії голок з клинами в'язальних систем.

Попередні дослідження показали, що у момент удару в'язальної голки об клин в її стержні виникають ударні хвилі напружень, що є однією з головних причин відмови голок (руйнування гачка голки та ін.). При цьому при рішенні задачі визначення величини напружень, що виникають в стержні голки, розглядається випадок жорсткого удару голки (стержня) об клин. Насправді ж при ударі голки об клин має місце пружний удар, зумовлений жорсткістю пари голка-клин.

Як показують дослідження, ефективним шляхом зниження динамічних навантажень, діючих на голку при роботі в'язальної машини, є зниження жорсткості пари голка-клин. Проте питання впливу жорсткості пари голка-клин на динаміку напружень, що виникають при цьому в стержні голки, практично не досліджене, що створює певні проблеми при проектуванні в'язальних машин.

Об'єктом досліджень обрана голка в'язальної машини і процес її взаємодії з клинами в'язальних систем. При рішенні завдань, поставлених в цій роботі, були використані сучасні методи теоретичних досліджень, що базуються на теорії поширення хвиль напружень в плоских стержневих елементах при подовжньому ударі.

Завданням досліджень є дослідження впливу жорсткості пари голка-клин в'язальної машини на напруження, що виникають при ударі голки об клин, та розробка методу впливу жорсткості пари голка-клин на ударні напруження в стержні голки при взаємодії її з клином в процесі в'язання.

Аналіз отриманих залежностей дозволяє прийти до висновку, що жорсткість пари голка-клин впливає на величину напружень в стержні голки, викликаних ударною хвилею. При цьому зниження жорсткості сприяє зниженню величини напруження в стержні голки.

Як відомо, голка має складну геометричну форму. Тому при ударі голки об клин в її тілі виникає складне поле напружень, яке залежить від геометричної форми голки. Отримані рівняння є лише деяким наближенням опису процесу зміни напружень в тілі голки при ударі її об клин. Проте отримані результати дозволяють зробити висновок, що зниження жорсткості пари голка-клин сприятливо впливає на підвищення довговічності в'язальних голок.

Ключові слова: в'язальна машина, голка, клин, напруження в голці, жорсткість пари голка-клин.

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Statement of the Problem

The object of research is the knitting machine needle and the process of its interaction with the wedges of knitting systems. When solving the problems set in this work, modern methods of theoretical research were used, based on the theory of shock wave propagation in flat stem elements during longitudinal impact.

The research objective is to investigate the influence of the inflexibility of the needle-wedge pair of a knitting machine on the tensions that arise when the needle hits the wedge, and to develop a method for the influence of the inflexibility of the needle-wedge pair on the impact tensions in the needle stem during its interaction with the wedge during the knitting process.

Analysis of Recent Sources

The efficiency of knitting machines, in particular their productivity and fabric quality, largely depends on the durability of the needles [1, 2], which, in turn, depends on the dynamic loads that arise in the zone of impact interaction of the needles with the wedges of knitting systems.

Studies [3] show that an effective way to reduce the dynamic loads acting on the needle during knitting machine operation is to reduce the inflexibility of the needle-wedge pair. However, the issue of the influence of the inflexibility of the needle-wedge pair on the dynamics of tensions arising in the needle stem has not been practically studied, which creates certain problems in the design of knitting machines.

Presentation of the Main Material

The studies et al. have shown that when the knitting needle hits the wedge, impact shock waves arise in its stem, which is one of the main causes of needle failure (destruction of the needle hook, etc.). When determining the magnitude of tensions arising in the needle stem, the case of a hard impact of the needle (stem) against the wedge is considered. But actually, when the needle hits the wedge, an elastic impact occurs due to the inflexibility of the needle-wedge pair.

When considering the propagation of shock waves arising at the moment of impact, let's consider the stem, the diagram of which is shown in Fig. 1, a. Let's take the axis of the stem as the X-axis. The impact force is applied to point O of the stem.

Assume the following initial conditions: $t = 0$ $u = 0$; $\frac{\partial u}{\partial t} = 0$; boundary condition $(x = 0)$:

$$EF\frac{\partial u}{\partial x} = -N(t), \tag{1}$$

where $u = u(x,t)$ is the longitudinal displacement of the stem cross-section during impact;

E is the module of normal elasticity of the stem material;

F is the cross-sectional area of the stem;

$\frac{\partial u}{\partial x} = \varepsilon$ is the relative elongation of the stem;

$N(t)$ – is the compressive force of the stem caused by the impact.

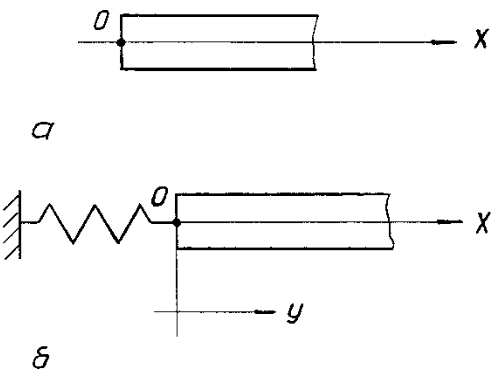

Fig. 1. Calculation diagram for analyzing the propagation of an elastic longitudinal shock wave in the needle stem of a knitting machine: a - when the needle hits the wedge with a hard impact; b - when the impact is elastic

It is apparent that: $N(t$ b f $t \leq 0$.

The displacement of th cross-sections at the moment of impact is described by the differential equation:

$$\frac{\partial^2 u}{\partial t^2} = a^2\frac{\partial^2 u}{\partial x^2}, \tag{2}$$

where $a = \sqrt{\frac{E}{\rho}}$ is the speed of sound propagation in the stem material;

ρ is the mass linear density of the stem material.

Let's assume that a longitudinal wave propagates along the stem:

$$u = f(x - at), \tag{3}$$

which satisfies the equation (2).

Then the equation of the stem cross-sections motion can be represented as follows:

$$\frac{\partial u}{\partial x} = f'(x - at). \tag{4}$$

Solving equation (4) using boundary conditions, we have:

$$EFf'(-at) = -N(t).$$

Therefore:
$$f'(-at) = -\frac{N(t)}{EF}. \tag{5}$$
Let's write expression (5) in the form:
$$-\frac{1}{a}\cdot\frac{d}{dt}f(-at) = -\frac{N(t)}{EF},$$
or in the form:
$$\frac{d}{\mathrm{dt}}f(-at) = \frac{aN(t)}{EF}. \tag{6}$$
We'll find the solution to the equation (6) using the method of variation of an arbitrary constant, by integrating:
$$f(\text{-at}) = \int_0^t \frac{aN(\tau)}{EF}d\tau = \frac{a}{EF}\int_0^t N(\tau)\,d\tau. \tag{7}$$
From equation (7), we have:
$$f(x-at) = \frac{a}{EF}\int_0^{t-\frac{x}{a}\geq 0} N(\tau)d\tau = u(x,t).$$
Using the obtained dependence (7), we can find the longitudinal displacement of the stem cross-sections during impact.

Let's consider the case of a needle stem impact, taking into account its elastic properties (elastic impact) - Fig. 1, b.

When the stem is impacted, the longitudinal displacement of its cross-sections is determined by the condition:
$$W = u(\mathrm{x},t) + v_0 t,$$
or, considering (7):
$$W = \frac{a}{EF}\int_0^{t-\frac{x}{a}\geq 0} N(\tau)\,d\tau + v_0 t, \tag{8}$$
where W is the longitudinal displacement of the stem cross-section during impact (elastic impact);

v_0 is the initial velocity of the stem (impact velocity).

The compressive force on the stem caused by the impact is found from the equation:
$$N(t) = cy(t), \tag{9}$$
where c is the inflexibility of the stem in the impact zone.

Substituting (9) into (8), we find:
$$W = \frac{ac}{EF}\int_0^{t-\frac{x}{a}\geq 0} y(\tau)\,d\tau + v_0 t. \tag{10}$$
Equation (10) can be represented as follows:
$$\frac{\mathrm{ac}}{\mathrm{EF}}\int_0^t y(\tau)d\tau + v_0 t = y(t). \tag{11}$$
Solving equation (11), we have:
$$\frac{ac}{EF}y(t) + v_0 = \frac{d}{dt}y(t),$$
or:
$$y'(t) - \frac{ac}{EF}y(t) = v_0. \tag{12}$$
Solving (12), we find:
$$y(t) = -\frac{EF}{ac}v_0 + Ae^{\frac{ac}{EF}t}. \tag{13}$$
We find the integration constant A using the initial conditions: $t = 0\ y(t = 0)$:
$$A = \frac{EF}{ac}v_0. \tag{14}$$
Substituting (14) into (13), we have:
$$y(t) = \frac{EF}{ac}v_0\left(1 - e^{\frac{ac}{EF}t}\right). \tag{15}$$
We'll determine the compression force of the stem by substituting (15) into (9):
$$N(t) = \frac{EF}{a}v_0\left(-1 + e^{\frac{ac}{EF}t}\right). \tag{16}$$
The stress in the stem cross-sections during impact will be equal to:
$$\sigma(t) = \frac{N(t)}{F} = \frac{E}{a}v_0\left(-1 + e^{\frac{ac}{EF}t}\right). \tag{17}$$
Representing the needle as a stem with a piecewise-variable cross-section [5], we'll find the maximum stress in the cross-sections of individual sections of the stem from the condition (taking into account that $\sigma(t)_i = \sigma_{imax}$ and $t = \frac{2l_i}{a}$):
$$\sigma\frac{Ev_0}{a}\left(-1 + e^{\frac{2cl_i}{EF_i}}\right)_{imax}. \tag{18}$$

Conclusions

Analysis of the obtained dependencies (17), (18) allows us to conclude that the inflexibility of the needle-wedge pair affects the magnitude of the tensions in the needle stem caused by the shock wave. At the same time, a decrease in inflexibility contributes to a decrease in the magnitude of the tensions in the needle stem.

As is known, the needle has a complex geometric shape. Therefore, when the needle hits the wedge, a complex stress field arises in its body, which depends on the geometric shape of the needle. The obtained equations (17), (18) are only some approximation of the description of the process of changing the tensions in the needle body when it hits the wedge. However, the results obtained allow us to conclude that reducing the inflexibility of the needle-wedge pair has a positive effect on increasing the durability of knitting needles.

Analysis of the current state of research on dynamic loads in knitting mechanisms of knitting machines and ways to reduce them, carried out on the basis of scientific research by domestic and foreign scientists and researchers, allows us to draw the following conclusions:

– dynamic loads in knitting mechanisms, caused by the impact interaction of needles with wedges, are a determining factor in the efficiency of knitting machines;

– the problem of reducing dynamic loads in knitting mechanisms exists and is relevant, since its solution allows to increase the productivity of knitting machines and the quality of knitted fabric and finished products;

– the most appropriate way to reduce dynamic loads in the knitting mechanisms of knitting machines is to improve existing and develop new needles and wedges, while, first of all, needles and wedges should be distinguished by higher flexibility of working zones (zones of working elements that interact with each other at the moment of impact);

– to date, there are no developments of a mathematical model of the dynamic interaction of a knitting machine needle with a wedge with an elastic element made in the form of a stop and a spring;

– there are no comprehensive studies assessing the effectiveness of using needles with a thinner shaft in the heel area to reduce dynamic loads in the knitting mechanism;

– the effectiveness of using needles with a ledge to reduce dynamic loads in the knitting mechanism has not been studied; there are no developments to improve this needle design aimed at reducing dynamic loads that arise in the area of its interaction with the wedge;

– despite the variety of knitting machine needle designs aimed at reducing dynamic loads in the knitting mechanism, further research into the development of more advanced and efficient needle designs remains relevant, while the needles should have a higher heel flexibility while meeting high requirements for the reliability of their work and obtaining high-quality knitted fabric [3].

The development of a method for determining loads in a needle (platen)–wedge pair with further development of the theory is an important stage in creating the theoretical foundations for the design of a knitting mechanism, as it will allow solving the problem of increasing the efficiency of knitting machines. This task is especially relevant at the present time, when the knitting machine industry is faced with the task of increasing the speed characteristics of knitting machines and automatic machines while simultaneously maintaining the quality of the products produced [3].

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